現代熱流量測技術

(Modern Measuring Techniques of Thermal Fluid Mechanics)

AM 5021 (3 credits, 應力館233, Wed. 14:20 ~ 17:20)

Chapter 1
Introduction to Course of "Modern Measuring Techniques of Thermal Fluid Mechanics" & Term projects

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What is belonging to "現代熱流量測技術"？

- **"Modern", "Thermal Fluid Mechanics" and "Measuring Techniques"**
- **Modern means "advanced" and "changing with time".**
- **力學為工程之根本**，一般概分為固體力學與流體力學，但很多的**量測技術原則都是相通的**。

Preface (I)

- 現代社會的**科研應用**:**跨領域**之普遍性與重要性。
- **實驗是檢驗理論的尺，也是發覺真理最直接的方法。**
- **實驗要做得好其實並不容易；看不見、難以捉摸涉及有「熱」與「流」的實驗要做得好，更屬不易。**
- **工欲善其事，必先利其器**，本課程以量測生活中有趣的、具未來發展性的熱流相關量測問題作為專題載具，搭配相關課程章節範例介紹，逐步引導無科研經驗、但對實驗量測有興趣的大學部及研究所同學們，如何由題目的選定、實驗計畫的擬定與執行、乃至最後成果的討論、撰寫與報告等過程，循序漸進有系統的實際參與，以達到實踐跨領域基礎科研訓練之目的。

Preface (II)

- 在課程中，將講授專題實作目標之背景知識；以及如何建立實驗系統、工程上常用的精密熱流實驗量測的相關學理與其應用、和不同實驗量測方法之優、缺點與限制，以建立同學們正確而廣泛的相關實驗量測基礎知識，同時配合不同專長同學的分組(最多兩人一組)，實際動手合作與交互驗證，以加強同學們對此課程知行合一與開發創意之訓練。

Preface (III)

- **Lecture Notes on Web: http://bernoulli.iam.ntu.edu.tw/, 進入「學術課程」, 再進入『現代熱流量測技術』**
- **Grading Policy: term project report and presentation: 100%**

Course Contents

- **Term project introduction & assignment (2/24)**
- **Introduction to modern measuring techniques of thermal fluid mechanics (3/3, 3/10)**
- **How to visualize your flow? (3/10, 3/17, 3/24, 3/31)**
- **1st Mid-term discussions (4/21)**
- **How to design and set up your experimental facility? (4/7, 4/14, 4/28, 5/05)**
- **How to quantitatively measure your system? (5/12, 5/19, 5/26, 6/02)**
- **2nd Mid-term discussions (5/26)**
- **Miscellaneous measurements (viscosity, surface tension, density, refractive index, thermal conductivity …etc.) (6/09, 6/16)**
- **Final Presentation & report (6/23)**

References

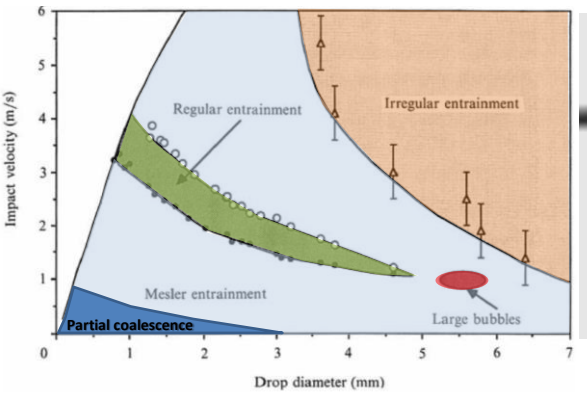
- **Reference: Springer Handbook of Experimental Fluid Mechanics, Tropea, Cameron; Yarin, Alexander L.; Foss, John F. (Eds.) , 2007, XXVIII, 1557 p. 1240 illus. in color. With DVD., Hardcover, ISBN: 978-3-540-25141-5**
- **(Authors Introduction) Book in NTU-library available**

Examples & What do we expect?

- 地表與人體大部分是液體，大自然 & 工業界 的例子…
- Example 1: 我們的靈魂之窗上面覆蓋(約10 μm厚)液膜、裡面不斷產生與傳送(約2.5 μL/min)的也是液體。液體會隨環境壓力、溫度的差異而流動，眼球長期受力會變形也是我們很多人有的(近視)親體驗…☹☺
- Example 2: 液體(滴)在微流體(microfluidics) 系統之行為與應用控制…
- Example 2: 液體在介面潤濕(wetting)行為的應用(如塗佈)與基礎研究…
- **I came, I saw, I conquered… Julius Caesar.**

Previous Topics of Term-projects (I)
(基礎研究領域)

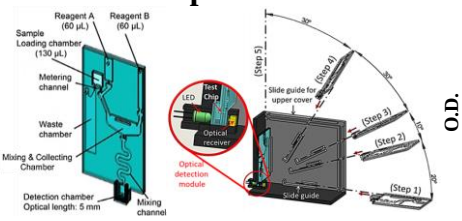
Large bubbles induced by drop impact

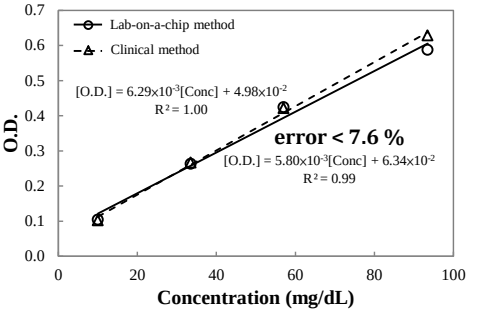


Parameters are drop velocity V & drop size only?

Previous Topics of Term-projects (II)
(生醫POCT應用領域)

Urine chip





Clinical method:

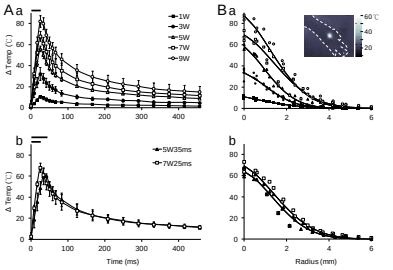
(TBA-200FR, Toshiba)

The new design is suitable for POCT in remote areas even without electricity.

Sensors and Actuators –B: Chemical, 222 pp. 721–727, 2016 (SCI [**IF=7.1**])

Previous Topics of Term-projects (III)
(神經生物與認知科學: 痛覺領域研究)

- **High speed dynamic temperature measurement** for skin surface
  (Temporal and spatial temperature distribution of rat's glabrous skin induced by short-pulse CO_2 laser, cooperation with Profs. 嚴震東& 趙福杉, published in **Journal of Biomedical Optics,** 17 (11), 117002, 1-8; (SCI [**IF=2.785**])



Recent Topics of Term-projects (IV)
(生醫應用領域 Blood Glucose Tester)

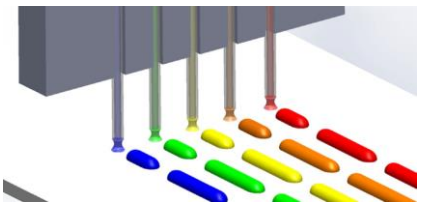
http://healthycomm.net/

test region

Screen printing → Direct stripe coating

Material saving ~ 90%

Reagent coating on PCB

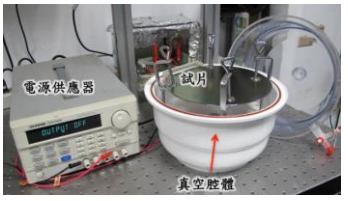


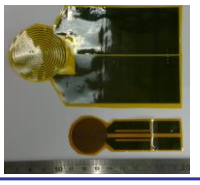
Smart Science, Vol. 4, 151-159, 2016

Previous Topics of Term-projects (V)
(先進電子材料領域)

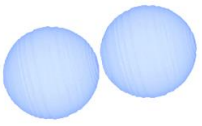
- **Thermal conductivity measurement** for high k thin plate (CSIST project)
  ("以暫態平面熱源量測技術快速量測材料熱性質之探討", 2012台灣熱管理協會年會暨技術成果發表會)

方法	穩態量測	暫態量測
設備示意圖		 $R_x(t) = R_0\left[1+\alpha\overline{\Delta T(t)}\right]$
時間	90分鐘	5秒-20分鐘
範圍	<10W/mk	0.005-500W/mk
成本	七十萬	★兩百萬★
體積	大	小

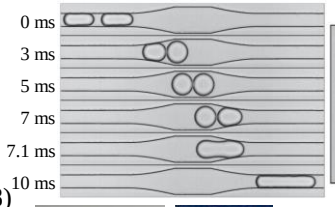


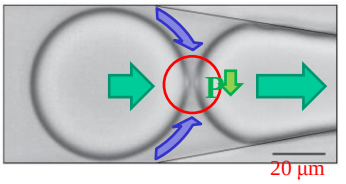


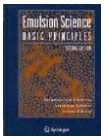
Recent Topics of Term-projects (VI)
Emulsion Droplets Coalescence



PRL **100**, 024501 (2008)

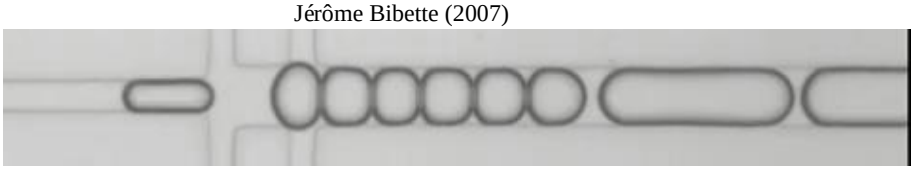






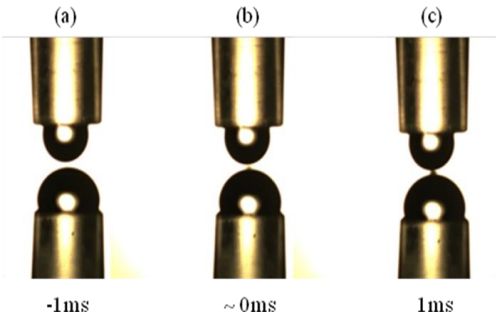
Jérôme Bibette (2007)

The separation of droplets favors coalescence!



Recent Topics of Term-projects (VII)
(光學量測領域)

- **Drop impact dynamics** Drop-drop coalescence **and measuring techniques** (undergraduates)
  (Illusive Effects of Generating Nipples between Two Coalescing Water Droplets, The twelfth Asian Symposium of Visualization (ASV#12), 2013)



Recent Topics of Term-projects (VIII)
Projector dynamics

Low velocity

High velocity

Other parameters:
1. Liquid properties
2. Roughness of sphere
3. Wettability of sphere … etc.

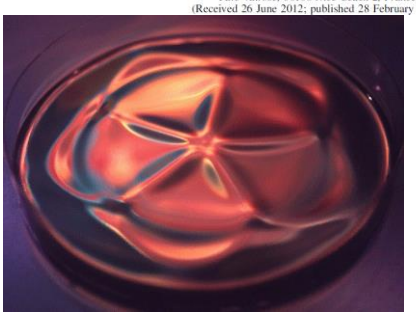
Steel sphere (D=3.95mm) impact onto water pool

Recent Topics of Term-projects (IX)
Observation of Star-shaped surface Gravity waves

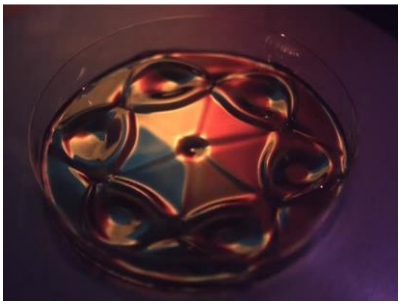
PRL 110, 094502 (2013) PHYSICAL REVIEW LETTERS week ending 1 MARCH 2013

Observation of Star-Shaped Surface Gravity Waves

Jean Rajchenbach,[1,*] Didier Clamond,[2] and Alphonse Leroux[1]
[1]*Laboratoire de Physique de la Matière Condensée (CNRS UMR 7336) Université de Nice—Sophia Antipolis, Parc Valrose, 06108 Nice Cedex 2, France*
[2]*Laboratoire Jean-Alexandre Dieudonné (CNRS UMR 7351) Université de Nice—Sophia Antipolis, Parc Valrose, 06108 Nice Cedex 2, France*
(Received 26 June 2012; published 28 February 2013)



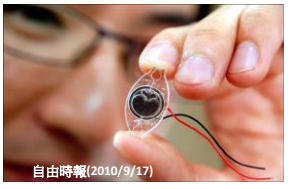
a vibration amplitude of 1.95 mm (filling level 7 mm, $\Omega/2\pi$= 8 Hz)

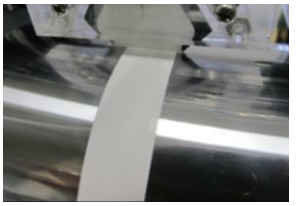


Symmetry of 6th order, (filling level 8 mm, vibration amplitude 2.90 mm, $\Omega/2\pi$ =12 Hz

Recent Topics of Term-projects (X)

- **Capillary ratchet** ?
- **Gone with the wind**
- **Real-time pressure monitoring in a micropump**
- **Splashing of different drops onto liquid film**
- **Visualization of flow within coating die**
- **Preventing Ice Adhesion to Metal**
- **Constant velocity microchannel design …**





Possible New Topics in 2021
現代熱流量測技術應用流體力學專題

1. 液體在固體表面移動之操控與量測 (孫廷瑋)
2. 液體在超疏水固體表面移動之力學機制 (賴亮喆)
3. 功能性智慧隱形眼鏡設計、製作及量測 (柯瑋軒)
4. 新世代塗佈頭設計、製作及量測 (姜昱維)
5. 仿生實驗設計、製作及量測 (Capillary ratchet)
6. **Splashing of different drops onto liquid film**
7. **Gone with the wind**
8. **Preventing Ice Adhesion to Metal**
9. **Constant velocity microchannel design**
10. **…**

Centrifugal μ-Fluidics on Disk (I)

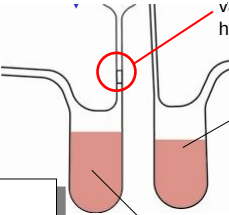
1. **liquid metering**
2. liquid switch
3. separation
4. mixing
5. detection

$$\boldsymbol{f}_{\nu} = -\varrho\boldsymbol{\omega} \times (\boldsymbol{\omega} \times \boldsymbol{r})$$

metering chamber with defined volume

overflow channel

- **Patent issue**
- **Stable motor & power are required**



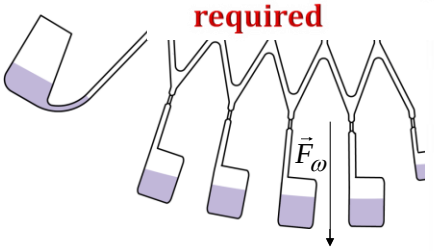
(Zengerle & Haeberle)

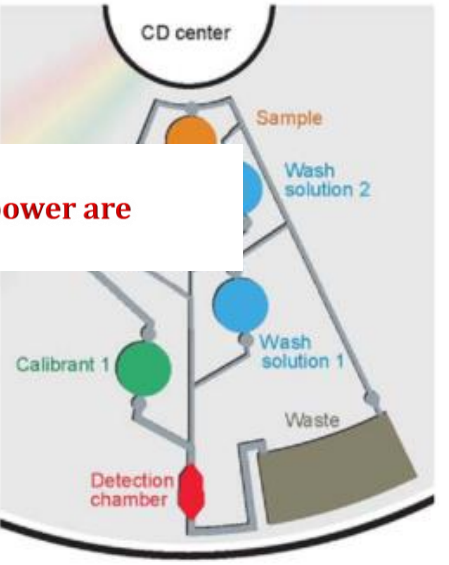
- Control by rotating speed
- Disposable & Low cost

Centrifugal μ-Fluidics on Disk (II)

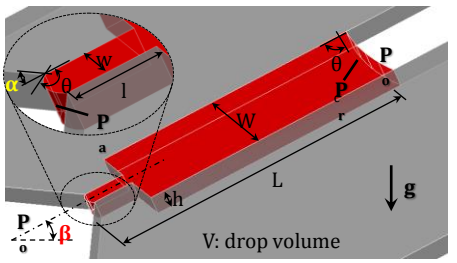
Splitting/Aliquoting for multi-channels

- **Patent issue**
- **Stable motor & power are required**





Design of Capillary-Gravitational Valve



$$\Delta P_a = P_o - P_a = 2\sigma\left[\frac{\cos(\theta_c + \alpha)}{w} + \frac{\cos\theta_c}{h}\right]$$

$$\Delta P_r = P_r - P_o = -2\sigma\cos\theta_c\left(\frac{1}{w} + \frac{1}{h}\right)$$

$$\Delta P_g = \Delta P_a + \Delta P_r = -\rho g L \sin\beta$$

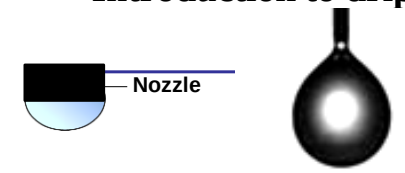
where $$L = \frac{\frac{V}{h} + (W - w)l}{W}$$

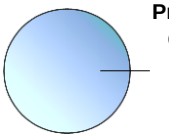
(Sensors and Actuators –B: Chemical, 222, pp. 721–727, 2016)

$$\beta_{op} = \sin^{-1}\left\{\frac{2\sigma W}{\rho g\left[\frac{V}{h} + (W - w)l\right]}\left[\frac{\cos\theta_c}{W} - \frac{\cos(\theta_c + \alpha)}{w}\right]\right\}$$

With an appropriate set of geometric design (**α,** w, W, h, and l), sequential control can be realized by simply changing β_{op}.

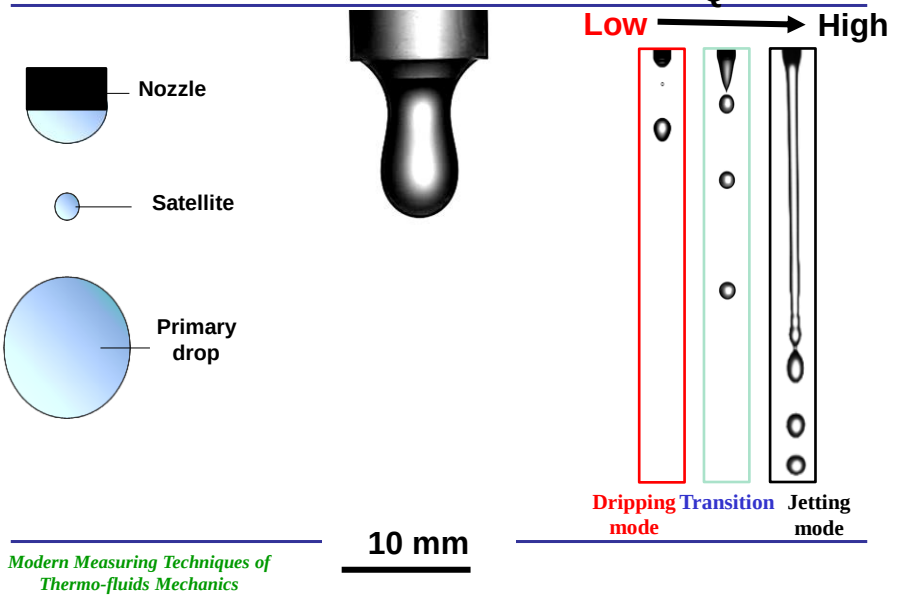
Introduction to dripping & oscillating drop(s)





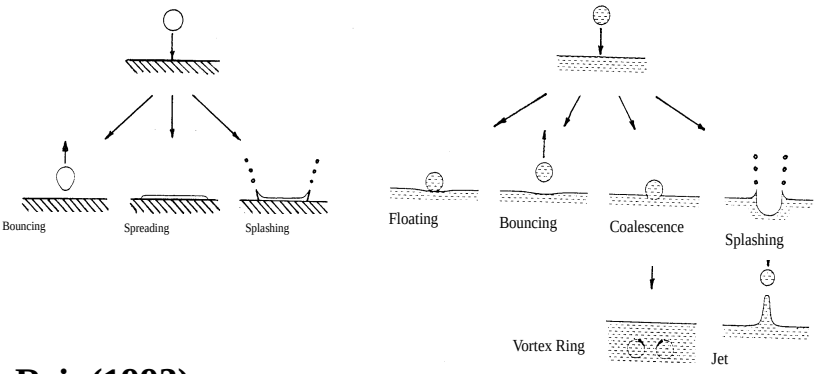
Widely appears in nature and our daily life

Dripping drop *vs.* *liquid feeding rate*



Single Drop Impact Phenomena

(a) **Impact on a dry Surface** **(b) Impact on a liquid film**

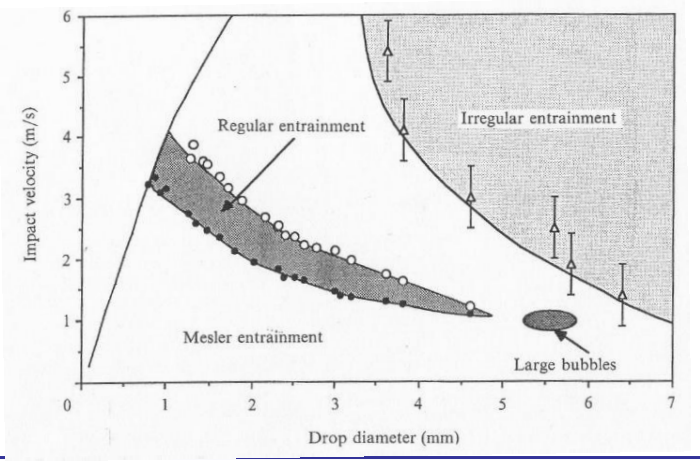


Rein(1993)

Classification of bubble entrainment

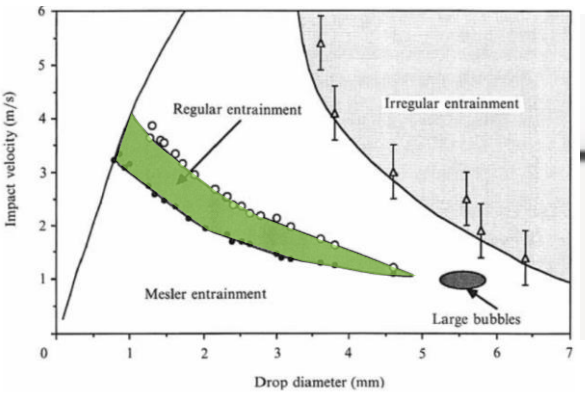
J. Fluid Mech. (1990) The entrainment of bubbles by drop impacts

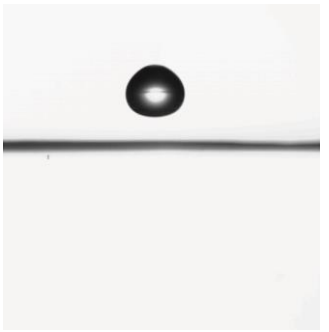
By HUGH C. PUMPHREY[1] AND PAUL A. ELMORE[2]



Regular Entrainment

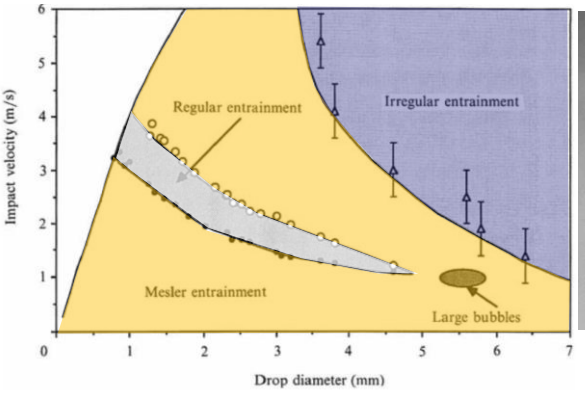
Bubble size: 0.1 ~ 1 mm

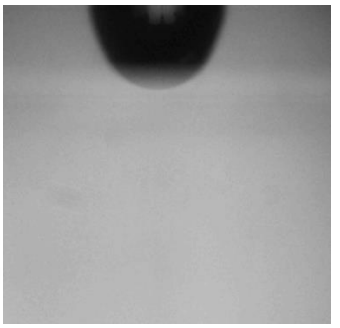




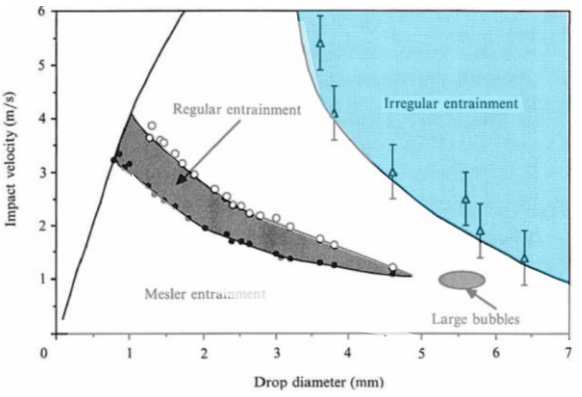
Mesler Entrainment

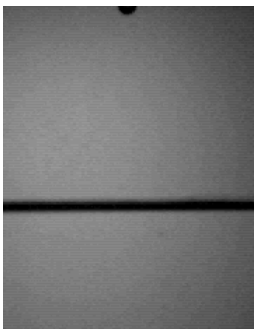
Bubble size ~ 50 μm





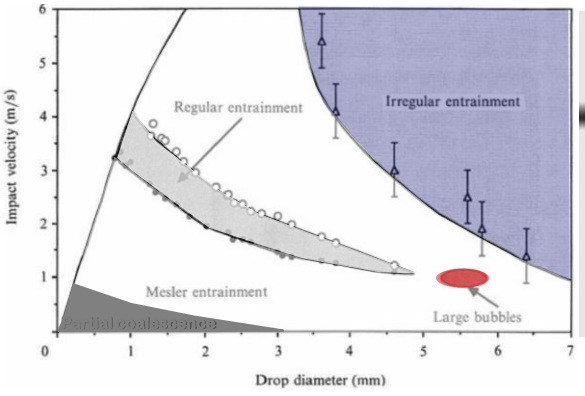
Irregular Entrainment



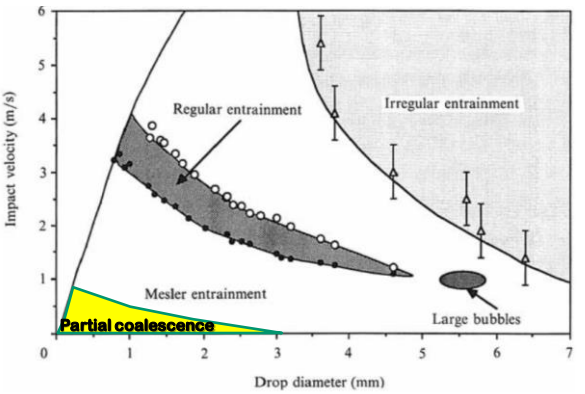


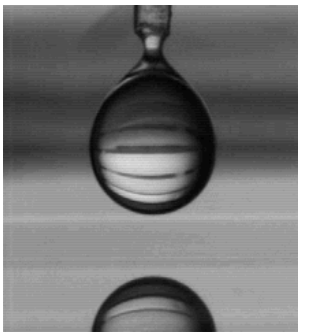
Large bubble Entrainment

Bubble size: 5 ~ 15 mm



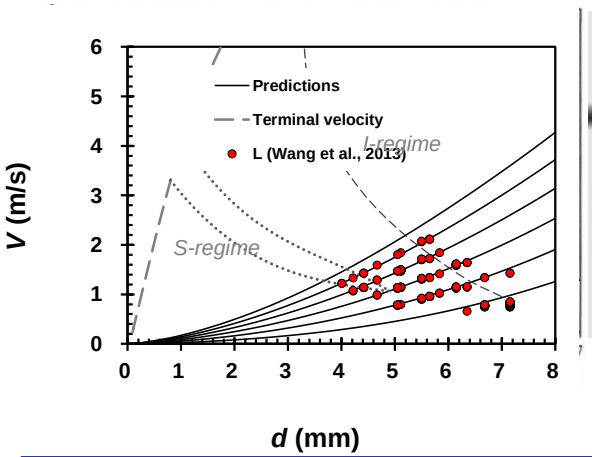
Partial Coalescence Regime





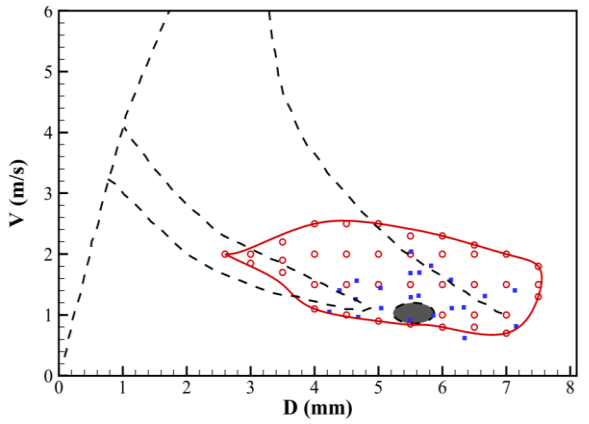
Formation of Large bubble Entrainment

Bubble size: 5 ~ 13 mm



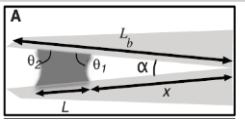
Formation of Large bubble Entrainment

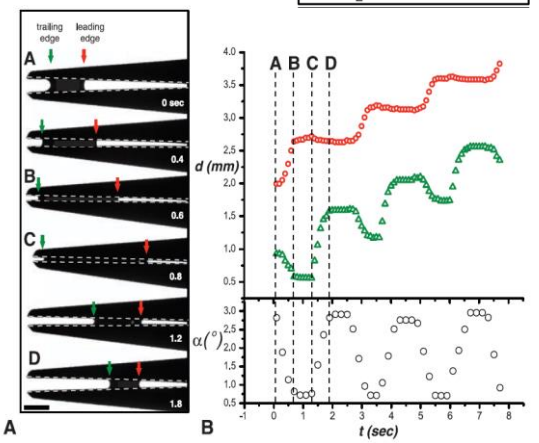
Simulation (Deka et al. Physics of Fluids 2017)

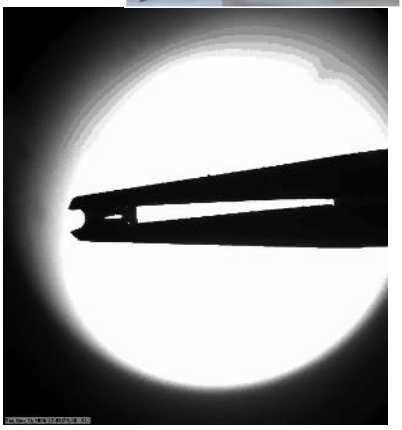


Capillary Ratchet (I)

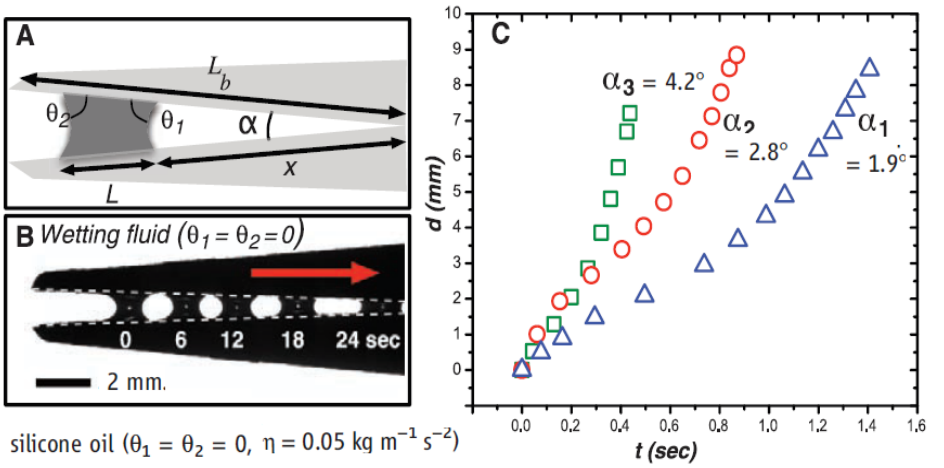
(Prakash, Quere, Bush, 2008, Science)







Capillary Ratchet (II)



(Prakash, Quere, Bush, 2008, Science)

Schedule of term projects

1. 2021/3/3 Determination of groups of term-projects
2. 2021/4/21 1st monthly discussions
3. 2021/5/26 2nd monthly discussions
4. 2021/6/23 final project presentation

(End of Chap 1)

~Thank you for your attention~